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Estimating and managing uncertainties in order to detect terrestrial greenhouse gas removals

Kristin Rypdal (CICERO) and Rainer Baritz (EU/JRC-IES)

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CICERO
Center for International Climate
and Environmental Research
P.O. Box 1129 Blindern
N-0318 Oslo, Norway
Phone: +47 22 85 87 50
Fax: +47 22 85 87 51
E-mail: admin@cicero.uio.no
Web: www.cicero.uio.no

CICERO Senter for klimaforskning
P.B. 1129 Blindern, 0318 Oslo
Telefon: 22 85 87 50
Faks: 22 85 87 51
E-post: admin@cicero.uio.no
Nett: www.cicero.uio.no

Tittel: Estimating and managing uncertainties in order to detect terrestrial greenhouse gas removals

Forfatter(e): Kristin Rypdal og Rainer Baritz
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Sammendrag: Data på utslipp og opptak av klimagasser vil inngå i rapporteringen til klimakonvensjonen og Kyoto-protokollen for å overvåke utslippsforpliktelsene som er inngått. Under forhandlingene om Kyoto-protokollen var det bekymring for at opptak av karbon i skog kan være vanskelig å verifisere. Årsaken til høy usikkerhet er store forskjeller i opptak mellom ulike geografiske områder og store årlige variasjoner, samtidig som en del nødvendige beregningsparametere aldri eller sjelden måles. En del spesielle avgrensinger av hva som kan rapporters under Kyoto-protokollen fører til ytterligere usikkerhet. I de nordiske landene vil skogtakseringsdata være svært nyttige for å beregne opptak av karbon i skog. Skogtakseringsdataene måler imidlertid først og fremst handelstømmer, og en stor usikkerhet ligger i oppblåsingen til endringer i totalt karbon. Usikkerheten i utslipp av andre klimagasser enn CO_2 og opptak og utslipp av karbon i jord er særlig høy. Opptak i skog, slik den skal rapporteres under Kyoto-protokollen, vil bare utgjøre en mindre andel av det totale opptaket slik at bidraget til å redusere totale utslipp blir forholdsvis lite. Samtidig er det ventet at de nordiske landene vil kunne implementere en relativt avansert metodikk. Følgelig er det ikke sikkert at den totale usikkerheten trenger å bli veldig høy.

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0318 Oslo

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Abstract: Inventories of emissions and removals of greenhouse gases will be used under the United Nations Framework Convention on Climate Change and under the Kyoto protocol to demonstrate compliance with obligations. During the negotiation process of the Kyoto protocol it has been a concern that uptake of carbon in forest sinks can be difficult to verify. The reason for high uncertainties are high temporal and spatial variability, and lack of representative estimation parameters. Additional uncertainties will be a consequence of definitions made in the Kyoto protocol reporting. In the Nordic countries, the national forest inventories will be very useful to estimate changes in carbon stocks. The main uncertainty lies in the conversion from changes in tradable timber to changes in total carbon biomass. The uncertainties in the emissions of the non-CO_2 greenhouse gases and emissions and removals of carbon from forest soils are particularly high. On the other hand, the removals reported under the Kyoto protocol will only be a fraction of the total uptake, and are not expected to constitute a high share of the total inventory. It is also expected that the Nordic countries will be able to implement a high tier methodology. As a consequence total uncertainties may not be extremely high.

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1 Introduction

Inventories of emission and removals of greenhouse gases will be used under the United Nations Framework Convention on Climate Change (UNFCCC) and under the Kyoto Protocol to demonstrate compliance with obligations. While the obligations under UNFCCC are more general, most industrialized countries have by signing the Kyoto Protocol undertaken specific obligations to limit their emissions.

The inventory of emissions and removals for the Kyoto Protocol will to some extent differ from the general inventory reported to UNFCCC. The inventory of emissions other than Land Use Land Use Change and Forestry (LULUCF) will be the same, while the inventory of emissions and removals from the LULUCF sector will be different. The UNFCCC LULUCF inventory is based on all managed forest. The Kyoto LULUCF inventory includes emissions and removals from afforestation, deforestation and reforestation (ARD, Article 3.3 of the Protocol) and on a voluntary basis forest management, revegetation and agricultural sources (grassland management and cropland management) (Article 3.4 of the Protocol). In addition, the Parties can meet their obligation through initiating projects on forest and other sources outside their own country and through emission trading.

In the negotiation process of the Kyoto Protocol there has been a concern that the uncertainty of the estimates reported for the LULUCF sector will be high, and that it can be difficult to verify reported removals.

In order to reduce uncertainties, it is important to understand their origin. The goal of this paper is to describe the main factors influencing the uncertainties of the estimates of CO_2 emissions and removals from the forest sector and how they affect the overall inventory uncertainties.

2 General inventory uncertainties

Uncertainties in "typical" emission inventories range from ±15-20 %[1] (Rypdal and Winiwarter 2001). Emissions of CO_2 from energy is typically low, less than ± 5 % in high quality inventories, while the uncertainty in emissions of other direct greenhouse gases (GHG) is higher (typically more than ± 20 %). However, the uncertainty in N_2O from soils can be particularly high, far higher than ± 50%. The reasons for high emission inventory uncertainties are typically that the processes creating emissions show high spatial and temporal variations and/or that there are few representative measurements that an emission estimation methodology can rely on.

In a statistical analysis errors are classified as random or systematic. Random errors can be identified in cases where emissions or estimation parameters are directly measured, or for the case of LULUCF, for parameters derived from the national forest inventory (NFI) which relies on representative samples of the total forest area. Systematic errors can be related to how measured values or samples are applied in the entire inventory of emissions or removals. Furthermore, emission inventories to a large extent rely on generalizations and expert judgments that will introduce additional uncertainty. It can be expected that systematic errors dominate overall inventory uncertainties (Rypdal and Winiwarter 2001).

[1] Uncertainties are expressed as two standard deviations.

3 Origin of uncertainties in the LULUCF sector

The estimates of emissions and removals in the forestry sector can have larger uncertainties than most other sources in the national inventory, especially if N_2O and CH_4 emissions from soils are also considered. The reason is partly that the fluxes will show high temporal and spatial variability, so that simplified emission models are not always applicable, and uncertainties originating from upscaling from plot level to a national scale can be very high. N_2O and CH_4 can only be incorporated on the basis of emission measurements from a few sites or using general emission factors. On the other hand, CO_2 emissions or removals are usually assessed either from models that take into account annual forest stand increments, or from the measurement of carbon in the biomass at different times (the annual change in carbon stored in biomass can be estimated from the difference between the results from repetitive forest inventories). Neither of these two approaches fully considers all biomass pools: some are roughly estimated (branches, twigs, sometimes coarse roots and leaves through use of biomass expansion factors), others are fully omitted (fine woody debris, fine roots, ground vegetation, and often also dead wood).

Error propagation can be used to yield the combined uncertainties from all the estimation parameters (stem volume, stand or tree level parameters needed for allometric BEF, roots, etc.) that are required. Additional uncertainties are introduced by the overlapping effects of prior land use and forest management intensity, which might last several decades and thus bias the effects of a management change. Therefore, additional historical data are required in order to identify the driving factors for carbon storage, and in order to determine the validity of default values for the change in carbon pools in biomass and soils. It has to be generally considered that the available data and methods (to measure the relevant estimation parameters such as stem volume) were not developed and applied to provide information about carbon storage, but rather, for example, on tradable timber volume. The statistical data is normally only available at interval years (5-10 years).

The main characteristics of LULUCF data are described in Table 1.

Table 1. Characteristics of LULUCF Data

Type of data	Data characteristics
fluxes (direct emissions/removals)	• emissions are comparably low (especially N_2O and CH_4) compared to the size of the storage pools • temporal and spatial variability is large • the system borders are difficult to determine due to the complexity of physiologically active ecosystem compartments • measurements of direct emissions are very cost intensive • uncertainties are especially high when estimating direct fluxes
carbon storage (in biomass and soils)	• not all biomass pools are accounted for in measurements (ground vegetation, coarse roots, etc.), and the pool sizes cannot not be directly determined from regular inventories • biomass carbon stocks are mostly (indirectly) assessed using models (BEF) (even direct biomass measurements use models for representative sampling) • soil carbon stocks can only be assessed from concentration measurements using pedo-transfer rules or measurements of bulk density • many countries lack the necessary infrastructure to conduct large/scale measurements of the estimation parameters needed to determine forest biomass (e.g. representative forest inventories) • national inventories are often staggered (e.g. different regions are completed in different years) and often have ca. 10 yr. return intervals ("periodic inventories" vs. annual inventories) • small differences in carbon stocks from large storage pools are difficult to detect
source/sink capacity of forests (emissions/removal rates)	• basic assumption: fluxes are equal to changes in carbon stocks in biomass and soils • disturbances reflect spontaneous events changing emission rates/defaults, and can offset regional sink effects • silvo-genetical cycles/forest stand developments have to be considered before long-term averages can be derived • non-linear development of C-stocks during stand development has to be considered because of positive and negative feedback mechanisms (e.g. effects of clear cutting) • non-steady state/direction of net fluxes can change over time. There is an upper, though mostly unknown, threshold as the limit for the maximum biomass storage capacity
management effects	• forest harvest is not necessarily a net source due to storage of carbon in forest products • forest harvests might change the source/sink behavior in the UNFCCC reporting category 5A • present and future CO_2 fluxes are affected by changes in land use (past land-use activities always have to be considered) • carbon pool compartments react differently (e.g. different lag times for response reaction) after implemented management measures
Additional uncertainties related to definitions and annual accounting	• there are little or no data available for ARD • spatial and temporal variability in terrestrial ecosystems is high • lack of directly measured data for the baseline for projects in most countries • lack of infrastructure to assess lands with activities under articles 3.3 and 3.4 of the Kyoto Protocol • uncertainties in base year emissions for net-net accounting

4 Types of generic error for biomass and soil C estimates

Table 2 provides an overview of the various possible error types that can occur at the plot level and upscaling level. In general, plot level errors have to be distinguished from upscaling errors, especially for soils, where national inventory designs were not developed to detect the area extent of soil units, or soil strata. In contrast, the NFI sampling scheme allows determining various activity data, including the area proportion of the various NFI strata (forest type, age class, property status, etc.). A particular upscaling method is not required; however, the error is expected to substantially increase with increasing level of NFI stratification (e.g. eco-region, forest management type), especially if the other estimation parameters (e.g. biomass expansion factor) do not correspond to that stratification.

Random errors can occur in the sampling for the NFI. The error is determined straightforwardly on the basis of standard sampling theory, and is usually low. While random error can be reduced by increasing the sampling density, systematic errors are difficult to track and quantify.

Several particular challenges for error propagation in forest biomass and soil carbon inventories can be expected:

(1) The quantification of both biomass and soil carbon stock depends on the correct estimation of various **estimation parameters** which become combined in simple calculation equations/models. Each stock estimate then consists of a combination of errors. Errors occur from measurements as well as the application of measurement data, and have both a random and systematic component. The sound and complete estimation of *all* possible errors is crucial in order to yield reliable change estimates.

(2) Uncertainties related to the **calculation of annual carbon change rates** (annual biomass increment per forest type per unit area) on the basis of either extrapolated yield table data or from differences between two NFI. Yield tables are usually obsolete and cannot easily be adjusted (actually, either measurements from long term experimental growth studies or results from repeated regional/national NFI are required for that). The annual change rates derived from repeated inventories are assumed to be constant during the inventory interval. Changes in biomass allocation pattern, changes of the pollutant deposition regimes, inapplicability of the normal forest model due to major disturbances, etc. incorporate **systematic errors** into NFI evaluations. Such uncertainties are difficult to quantify, and are thus often excluded or roughly estimated by expert judgment. Table 2 also contains some examples.

When applying measurements data in a national inventory of emissions and removals, it is also important to consider additional systematic errors:

- Definition errors:
  - Definitions in the Protocol (can be difficult to implement)
  - Incomplete, unclear, faulty definitions;
  - Definitions are changed during/between inventories

- Natural variability:
  - Seasonal variability (change of natural site factors, labile pools, disturbance regimes)
  - Spatial heterogeneity (scale-dependent)

- Management-induced variability:
  - Anthropogenic effects not addressed by the management regime (e.g. gathering of fuel, extensive grazing, hunting regimes)
  - Effects of former land use
  - Effects from atmospheric emission input (NO_x)
  - Effects from side effects from neighboring land use (e.g. NH_4)

- Map errors for soils:
  - Soil mosaic/ soil composition under a specific land use is unknown (for top-down maps)

Table 2. Generic error components in forest inventory with specific references to the detection of biomass and soil carbon stocks and stock changes

generic error types	random component	systematic component
(a) plot/parcel		
sampling errors	- variability of repeated measurements	- subjective sampling deviating from sampling theory
measurement errors	- improper/incorrect measurements - wrong use of equipment (field/lab)	- incorrect calibration/analysis instruments
model errors	- inherent variability in the relationship between the response and the predictor variables	- incomplete/simple model - model that refers to the wrong population - incomplete attribution to the source/sink categories
classification errors		- incorrect identification of site factors (e.g. vegetation type, soil type, etc.)
(b) up-scaling		
sampling errors	- not all plots/parcels measured - insufficient representativity (sample-based method)	– biased distribution of sample points: e.g. sampling net-work in highly populated areas is denser than in less accessible areas – the map units (large-scale) for grid points are not correctly identified (top-down regionalisation)
classification errors		- remote sensing: definition of land use classes and their relations differs between data source and IPCC guidelines and good practice guidance - omission error - commission error

5 LUCF and inventory uncertainties

The magnitude of the uncertainties of emissions and removals will clearly depend on the method applied in the estimation and the quality of the available data.

If the estimates are based on the default method according to the IPCC (1996) guidelines, the uncertainty can be more than ±50 %, while it can be reduced if effort is spent on applying higher Tier estimation methods. In the case of soils, even the sign (emission or removal) can be uncertain in some cases (CarboEurope 2002).

The uncertainty in the estimate used in a national inventory of emissions and removals for reporting under the UNFCCC and Kyoto Protocol will depend on the available data and estimation methodology chosen. Denmark, Finland, Norway and Sweden have all systems of national forest inventories (NFIs) based on sampling that can form the basis for estimating emissions and removals of CO_2 from the forestry sector. Consequently they will probably be able to use the higher Tier[2] methods in the IPCC guidelines (IPCC 1996). Emissions and removals can in principle be estimated from differences in total stock between two NFIs[3]. It is, however, more common to apply average growth rates on a NFI baseline.

This involves the following data:

- biomass stock from an initial NFI
- annual average biomass growth rate (increment)
- annual loss of biomass (harvest and waste)

The uncertainty in each of these parameters has to be combined to assess the uncertainty of the total estimate of carbon emissions and removals.[4]

5.1 Uncertainties in biomass stock

The uncertainty in the inventory originates from sampling and upscaling in order to obtain stem volume estimates for the country. Various so-called activity data (area extent of forests, forest types, etc.) and other[5] estimation parameters and factors (biomass expansion factors to account for roots, leaves and branches, etc., wood density, carbon content) are needed to relate stem volume to biomass stocks. The uncertainty in the carbon content factor can be considered low (less than 5 %), while the uncertainty of wood densities can be slightly higher (10-20 %). The most uncertain parameter is normally the biomass expansion factor. This parameter can be very uncertain if based on general default values. These expansion factors can be even more uncertain when applied on land use change, where the forest can be very young. This can affect the quality of reporting under the Kyoto Protocol.

[2] The concept of **Tiers** has been introduced in the **IPCC Guidelines**; a Tier refers to a specific accounting method and relates to differences in data availability. The higher tier approaches involve widespread use of country specific information, for example an increasing number of measurements and (i.e. larger number of trees and tree growth measures, as well as soil sampling for further analysis of carbon contents) that would allow improved, "more accurate" estimates, higher representativity and thus a lower up-scaling error.

[3] In this case it is important to assure that the land coverage is the same.

[4] Approaches to **combine uncertainties** in inventories are suggested in IPCC (2001). See also Winiwarter and Rypdal (2001).

[5] The basic **activity data** (or **estimation parameter** for biomass carbon stock) in forestry is the stem volume (for various inventory strata, e.g. forest type, tree species in a given eco-region, etc.).

5.2 Uncertainties in annual biomass growth rate

The NFI can be used to obtain data on biomass growth rates (in combination with models, such as yield tables, or repeated inventories). The natural variability of growth rates is extremely high, so that reliable and valid average growth rates according to age class, fertility and forest management practices, etc. are difficult to assess. The overall uncertainty will mainly depend on the NFI sampling design, and the capacity to update growth models.

5.3 Uncertainties in annual loss of biomass

Forestry statistics provide information about the commercial harvest intensity. In the northern European countries, the uncertainties can be assumed to be quite low due to the annual updating and the internal accounting systems (amount of harvest of various timber sorts is the main activity data in forestry). However in this calculation scheme, non-commercial fuel wood production and associated harvest waste, is not accounted for. These parameters are likely to be rather uncertain. Finally, natural losses from spontaneous disturbance also have to be taken into account. Natural internal mortality is incorporated into yield models; however, changes of mortality (and thinning intensity) due to management changes and differences in litter and debris supply are usually not sufficiently incorporated.

5.4 Additional systematic errors when applying the NFI for CO_2 estimates

In addition, other factors also contribute to the overall uncertainty:

- The NFI does not necessarily cover all managed forest.
- The estimates shall cover managed forest. However, it is not always straightforward to distinguish managed and "natural" forest in the Nordic countries.
- The NFI does normally not provide annual data. Data are collected in intervals and are often averaged before publication. When data for new intervals become available, it can sometimes be difficult to assess consistency with old periods. Thus interpolated and extrapolated values have to be applied on the estimations. Data will often not refer to the inventory year, but an average of for example 5 years
- Disturbances such as forest fires and damage due to storms has to be taken into account though data can be scarce

For the **Kyoto Protocol reporting** it is important to distinguish between emissions and removals due to changes in biomass in existing areas and areas converted to and from forest, while double counting needs to be avoided. It is also required to distinguish between natural re-growth on abandoned managed land and human induced reforestation/afforestation. Reporting to the Kyoto Protocol is to be based on changes since 1990 (in the commitment period).

5.5 Uncertainties in forest soil carbon

Soil carbon stocks and changes in soil carbon can be extremely uncertain. Not only are forest soils highly spatially heterogeneous, changes from historical land use and prior management intensity produce overlap effects with the current management practice. At the plot level, uncertainties depend on the method chosen for sampling to derive carbon stocks from concentration measurements.[6] For a reliable estimate of carbon stocks in the soil, the correct determination of the soil volume which is able to store carbon is crucial (**amount of fine earth**). The estimate of the fine earth volume is strongly dependent on the **stone content.**[7] It is a well-known fact that an increasing amount and probably also size of stones (and **coarse roots**) substantially increases the uncertainties of the soil stock estimate.

Due to the low relative mass of **fine roots** compared to the overall carbon stocks in soils, and due to their short life times and sampling difficulties, fine roots are usually assumed to be represented in the soil carbon determination (although root respiration represents an important component in the greenhouse gas balance of forest soils).

Given the very high natural and human-induced uncertainties, no cost efficient and operational inventory method seems to be feasible to provide reliable forest soil carbon stock change estimates within the required UNFCCC reporting timeframe. The detection of soil carbon changes within national inventories might require up to 20 yrs. (Arrouays et al. 2002), or sampling densities of up to 10,000 (for Sweden) (Olsson 2002).

5.6 Total LULUCF uncertainties

Most of the Nordic countries have a high contribution from carbon removals in forest in their inventory. Furthermore, the overall uncertainty of this is sink is expected to be higher than the average inventory uncertainty of ±15-20% (although the actual uncertainty is difficult to assess), so the inclusion of LULUCF will in general increase the overall inventory uncertainty.

5.7 Kyoto Protocol uncertainties

Concerning the Kyoto inventory, the same considerations apply to some extent. Uncertainties are in general expected to be lower than for the full UNFCCC inventory because specific monitoring systems will have to be installed in order to fulfill the reporting requirements. This is in contrast to UNFCCC greenhouse gas inventories, where existing national forest inventory programs are modified to provide large-scale biomass and soil carbon data. So if forestry is a key (important) source or sink, it is anticipated that countries apply a higher Tier method (IPCC 2001). It can be expected that the various error components can be tracked in a more quantitative manner rather than by expert judgment, and that upscaling errors might be reduced because of improved criteria of representativity that need to be fulfilled. If Kyoto Protocol reporting (e.g. forest management projects) will be attempted on the basis of the existing inventories and national monitoring programs, higher errors will result due to the decrease of sampling density while the non-statistical errors remain as high as for the whole country.

On the other hand, the requirement of detecting changes in land areas applied under the Kyoto Protocol and definitions included in the Protocol can lead to somewhat higher uncertainties. The contribution of the Kyoto inventory sink in relation to national total emissions will also normally to be lower than for the UNFCCC inventory.

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[6] The approach to estimate **bulk density** (BD) on the basis of pedo-transfer rules (based on auxiliary parameters) implies higher uncertainties than the use of analyzed BD from ring samples (possible for soils with low stone contents).

[7] The amount and spatial distribution of coarse roots have a similar effect on the quality of the fine earth estimate.

6 Managing uncertainties

Because the uncertainties of estimated emissions and removals in the LULUCF sector are higher than in most other parts of the emission inventory, it can be a matter of concern with respect to the reliability of emission data reported. The requirement for high-quality emission data, however, encompasses more than accuracy. There are also requirements, for example, for transparency (documentation) (IPCC 2001). The IPCC is currently preparing specific guidance for good practice and uncertainty management for the LULUCF sector that will apply both to the UNFCCC and Kyoto Protocol reporting requirements. This includes decision trees for methodological choice.

Emission estimates submitted should be made in accordance with the IPCC guidelines (IPCC 1996). The IPCC has in 2002 been working on a report with more specific methodological guidance on good practice for the LULUCF sector. This report will also address reporting under the Kyoto Protocol. Reporting guidelines and good practice guidance should guide each country to the correct choice of methodology given national circumstances. The ambition level will depend on the relative importance of each source or sink with respect to the entire inventory (IPCC 2001).

Before the commitment period, Parties are encouraged and allowed to refine the methodology. This can be to move to a higher tier methodology, or to use better estimates of activity data and estimation parameters. To obtain consistency, this means that the whole time series often have to be updated (recalculated). In the LULUCF sector some activity data, for example the NFI, are not annually available. That means that data have to be extrapolated from the most recent inventory until a new NFI is established. The extrapolation values then have to be substituted by interpolated values, with a subsequent recalculation of emissions or removals.

In an inventory, key sources should be prioritized with respect to resources. Due to the high level of removals, forestry will likely be a key source (sink) in Finland, Norway and Sweden. Consequently, it will be required that particular attention is paid to implement a higher Tier methodology for forestry. This also includes the development of national (or Nordic) estimation parameters. A sensitivity analysis can help to prioritize efforts into the most important parameters.

All inventories of emissions and removals will be subject to a review performed by an international review team. This review is coordinated by the United Nation Framework Convention on Climate Change (UNFCCC). They will review all the important source-sectors, including LULUCF. The review team will describe whether they find that the inventory is made according to good practice and suggest improvements. At this stage, reviews are performed on a trial basis.

7 Conclusions

The inventories of emissions and removals of CO_2 from LULUCF in Denmark, Finland, Norway and Sweden are based on national forest inventories. The national forest inventories are developed for other purposes than estimating removals of CO_2, but they are still very valuable for the estimation. The overall uncertainty of an LULLUCF carbon inventory can be high, especially for afforestation and reforestation. In general the main uncertainties lay in the biomass expansion factors and changes in soil carbon. For the Kyoto Protocol reporting additional data will be needed, but requirement for advanced methods may still reduce the uncertainties. The IPCC is currently developing guidelines for methodological choice for the LULUCF sector for reporting the UNFCCC and Kyoto inventory. Due to the importance, forestry should be prioritized in the Nordic inventories of emissions and removals, including the determination of national estimation parameters. The inventories of emissions and removals reported under the UNFCCC and Kyoto Protocol will, as for other sources, be reviewed by an international expert team in order to assess whether the methods applied are according to good practice.

References

Arrouays, D, N. Saby, C. Jolivet and C. Germeau 2002. Uncertainties and soil monitoring: shall we detect changes in soil carbon over commitment periods? 4th Whole COST E21 action meeting, Valencia, 7.-8.Oct.2002. http://www.bib.fsagx.ac.be/coste21/.

CarboEurope 2002. Tree farms won't halt climate change. New Scientist News. October 2 2002.

Cullen, A.C. & Frey, H.C. 1999. Probabilistic Techniques in Exposure Assessment. A Handbook for Dealing with Variability and Uncertainty in Models and Inputs. New York- London: Plenum Press. ISBN 0-306-45957-4.

IPCC. 1996. IPCC Guidelines for National Greenhouse Gas Inventories. Vol 1-3. Intergovernmental Panel on Climate Change, London.

IPCC. 2001. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. J. Penman et al. (eds.), IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Japan.

Morgan, M.G. & Henrion, M. 1990. Uncertainty. A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis.Cambridge: Cambridge University Press. ISBN 0-521-42744-4.

Olsson, M. 2002. Monitoring sol organic carbon stock changes for forest land in Sweden – methods and constraints (in preparation).

Rypdal, K. 1999. An evaluation of the uncertainties in the national greenhouse gas inventory. SFT report 99:01. Norwegian Pollution Control Authority.

Rypdal, K. & Flugsrud, K. 2001. Sensitivity analysis as a tool for systematic reductions in greenhouse gas inventory uncertainties. Environmental Science & Policy, Vol 4, 2001, 117-135.

Rypdal, K. & Winiwarter, W. 2001. Uncertainties in greenhouse gas emission inventories - evaluation, comparability and implications. Environmental Science & Policy, Vol 4, 2001, 107-116.

Rypdal & Zhang, L-C. 2000. Uncertainties in the Norwegian Greenhouse Gas Emission Inventory. Reports 2000/13. Statistics Norway.

Winiwarter, W. & Rypdal, K. 2001. Assessing the uncertainty associated with a national greenhouse gas emission inventory: A case study for Austria. Atmospheric Environment. Vol. 35/32. 2001. 5425-5440